LOCATION SYSTEM COMBINING RANGING MEASUREMENTS FROM GPS AND CELLULAR NETWORKS

RELATED APPLICATION

Under Title 35 United States Code §119(e), this application claims the benefit of the filing data of U.S. Provisional Application No. 60/087,207, filed May 28, 1998.

TECHNICAL FIELD OF THE INVENTION

The present invention relates to mobile telecommunication systems, and more particularly to methods and arrangements for locating mobile terminals.

BACKGROUND

It is desirable, and in certain places mandated by law, that mobile telecommunication network providers be able to determine an approximate geographical location of a mobile terminal (MT), such as, for example, an actively communicating cellular telephone.

There are a variety of MT location techniques currently being tested or used. These location techniques can be grouped into three basic categories.

The first basic category includes "uplink signal" location techniques, wherein the mobile telecommunications network is configured to determine where the MT is located based on ranging measurements associated with one or more uplink signals, which are transmitted by the MT and received by a requisite number of receivers having known locations, such as, for example, cellular telephone base stations (BSs).

The second basic category includes "downlink signal" location techniques, wherein the mobile telecommunications network is configured to determine where the MT is located based on ranging measurements associated with the reception, by the MT, of downlink signals from a requisite number of transmitters having known locations.

The third basic category includes using location services not associated with either the uplink or downlink signals used in the mobile telecommunications network. One example, of such a location service is the Global Positioning System (GPS) in which GPS receivers collect and analyze ranging measurements from signals transmitted by GPS satellites having known locations. Currently, there are twenty-four (24)GPS satellites in orbit.

The location techniques in each of these three basic categories include collecting ranging measurements such as, for example, a time of arrival (TOA), a time difference of arrival (TDOA), an observed time difference (OTD), or the like. These ranging measurements are gathered by detecting one or more measurement features within the transmitted/received signal(s). Each of the various location techniques has certain limitations or drawbacks that can significantly reduce their accuracy.

By way of example, currently available or proposed TOA, TDOA, and OTD location techniques that utilize existing BSs typically require that at least three (3) or more BSs receive the transmitted uplink signal from the MT, or conversely that the MT receive transmitted downlink signals from at least three BSs to perform the locating process. Similarly, with respect to the GPS, a GPS receiver needs to receive transmitted signals from at least four (4) GPS satellites to perform the locating process.

Unfortunately, at certain times there is not always a clear line-of-sight (LOS) between the requisite transmitter(s) and receiver(s). For example, in an urban environment, the LOS is often blocked by building and/or other structures, while in certain other environments the naturally occurring terrain and/or other features (e.g., mountains, canyons, forests, weather, etc.) can reduce the LOS, attenuate the transmitted signals, or produce multipath signals at the receiver. For many higher frequency signals or weaker signals, the loss of LOS or the introduction of such obstacles, can render the location technique significantly inaccurate, or completely unavailable.

Consequently, there is a need for methods and arrangements that provide location techniques having improved accuracy, reliability, and/or accessibility.

SUMMARY

In accordance with certain aspects of the present invention, methods and arrangements are provided for locating a mobile terminal. The methods and arrangements combine terrestrial-based location techniques with satellite-based location techniques, resulting in improved accuracy, reliability, and accessibility. For example, considering the three basic categories identified in the Background section, above, the present invention provides various methods and arrangements for combining at least portions of the location techniques in the first and/or second categories with the location techniques in the third category.

Thus, for example, the above stated needs and others are met by a mobile terminal locating method, in accordance with certain embodiments of the present invention. The method includes receiving a signal from at least one satellite, and a signal from at least one terrestrial transmitter, using the mobile terminal. The method further includes measuring a "time of flight" for each of the received signals and converting each of the resulting time of flight measurements to corresponding range values. The range values are then used by the mobile station to determine its approximate position. In certain embodiments, the satellite is part of the Global Positioning System (GPS) and the terrestrial transmitter is a base station within a mobile telecommunications system. In still other embodiments the method also includes using a single time measuring unit, located within the mobile terminal, to measure the respective time of flights for both the first type of signals and the second type of signals.

In accordance with further embodiments of the present invention, an arrangement for use in a mobile terminal and a mobile telecommunications system is also provided. Each of these embodiments, includes at least one time measuring unit that is configured to receive a signal associated with at least one satellite and a signal associated with at least one terrestrial transmitter. The time measuring unit is further configured to measure a time of flight for each of the received signals, convert each of the resulting time of flight measurements to corresponding range values, and determine and output an approximate position of the mobile terminal using the range values.

In accordance with still further embodiments of the present invention, another method for locating a mobile terminal is provided. This method also meets the above stated needs and others and includes receiving a plurality of first type signals from a plurality of satellites, and transmitting at least one second type of signal to a plurality of base stations, using the mobile terminal. The method further includes measuring a time of flight for each of the first type of signals received at the mobile terminal and measuring a time of flight for each of the second type of signals received at the plurality of base stations. Additionally, the method